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ABSTRACT

Meta-analysis techniques were used to analyze the effects of different types of aids to learning science concepts from textual materials. The studies analyzed dealt with aids for selecting the important information contained in written materials and aids for building internal connections among the parts of printed materials. Studies pertaining to advance organizers or to student elaboration activities were not considered. Analyses show: (1) an overall average effect size, indicating that students may be aided in their understanding of science concepts from textual materials; (2) the overall effective was positive; (3) the effect size varied considerably depending upon the type of dependent measure; and (4) the results of blocking studies on other variables was not clear, and many of the computed effect sizes were small. These results indicate that most students can be expected to benefit from forms of textual structuring that aid them in selecting the important concepts and that also aid them in making internal connections within the presented materials. It is possible that computer presentation of textual materials will make this even more feasible. (JN)

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A META-ANALYSIS OF LEARNING SCIENCE CONCEPTS FROM TEXTUAL MATERIALS

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A META-ANALYSIS OF LEARNING SCIENCE CONCEPTS FROM TEXTUAL MATERIALS

Over the years in science education there have been many suggestions on how to enhance student's learning of science concepts from written materials. This has led to numerous theories and research studies dealing with the recall of printed material. These studies have analyzed many variables, yet Finley (1983, p. 47) still was able to state that relatively little is known about what students recall from their reading. He went on to state:

> "A common and implicit assumption in assigning reading materials in science class is that most students will recall approximately the same propositions they have read. However, recent reading research guided by the schema theory indicates that this may not be the case. This research suggests that recall is not a matter of retrieving what was read, but instead a process in which an interpretation of text meaning is constructed and later recalled. The constructed meaning is thought to depend upon the student's prior knowledge of subject matter, which was used to interpret the text. As a result of similarities and differences in prior knowledge, similarities and differences in what students recall from their reading assignments can be expected."

In a similar sense Ulerick (1983) stated that although learning from written text occurs at all levels very few studies specifically address the problems, practices, and outcomes of learning from text. The relevant studies do not consider much of the information processing models of learning which clearly suggest the importance of content in producing differential learning outcomes. The problem becomes even more complex when we consider the levels of learning that occur. Mager (1984) suggests that after reading a text some readers will not remember much information from the text (non-learners), some readers will remember much of the information from the passage but will not be able to use that information in creative ways to solve problems

(non-understanders) and some will not only remember but will also be able to apply the information in creative ways that apply to new situations (understanders).

With these points in mind, we may identify studies that have dealt with three main types of aids (Mayer, 1984). First there have been many studies dealing with aids for selecting the important information contained in the written materials. These include such things as underlining. Secondly, there have been studies dealing with the building of internal connections. These include such things as structured notetaking. Thirdly, there have been studies dealing with building external connections. These include such things as advance organizers.

While there have been reviews dealing with some of the studies in a qualitative sense, there have been no specific attempts in science education at quantifying the results in many of the areas. The great number and variety of studies indicate a need for integrating the results of the studies pertinent to science education. Additionally, with the growing useage of computers in the science classroom, it seems imperative to be aware of the procedures that have proved beneficial in learning from printed materials.

Purpose: The purpose of this paper was to report, in a quantitative sense, the results of an examination of the investigations related to learning science content from textual material. The study was limited to science content because previous research has shown that readers recall different expository forms differently. They rely on surface structure to provide information about the organization of the material. Kintesch, Kozminsky, Sterby, McKoon, and Keenan (1975) found that

social studies text was recalled more completely than science text. Thus the content of the lesson may be of relative importance when comparing research studies. It was also decided to include only studies which dealt with the first two types of aids. That is those studies that involved helping students select the important aspects of the written material and those that aided the student in building internal connections within the textual materials. Thus studies which pertain to advance organizers and student elaboration activities were eliminated. Studies which included training students in procedures to use when reading text were also not considered. The third type of aid was felt to be more responsive to prior knowledge or schema. In a sense they may be thought to be more responsive to confounding variables. Additionally, Luiten, Ames, and Ackerson (1980) have previously conducted a meta analysis of research studies dealing with advance organizer covering all content areas.

Procedure: Meta-analysis, a procedure developed by Glass (1976), was employed to integrate the results. The meta-analysis procedure allows a person to look at various studies and compute a statistic known as an "effect size". The effect size from many studies may be combined by computing an overall effect size. This gives us a measure of the overall effectiveness of the studied variable. This approach to the synthesis of research is actually the attitude of data analysis applied to quantitative summaries of individual studies. By coding quantitatively the properties of studies and their findings one is able to integrate numerous and diverse studies.

In order to identify the relevant research studies, a search was

done of several data bases. These included the Education Index, the Resources in Education, and the Current Index to Journals in Education. Additionally, extensive use was made of the yearly reviews of research in that are published in Science Education. Lastly the abstracts of presented papers at NARST were reviewed to identify studies which were not reported in educational journals. The search was limited to studies which involved textual materials related to science and also to studies which were carried out between 1975 and the present time. As previously mentioned, the first constraint was applied because it was felt that the structure of the various disciplines might possibly affect the outcomes. The time constraint was chosen to limit the search to studies which are based upon the theoretical considerations of mathemagenic behavior outlined by Faw and Waller (1976).

Relevant characteristics of the research studies were identified and coded. Coding of these characteristics allowed the uniform examination of differing design features, dependent variables, and outcomes. The design features included such things as length of textual passage, time of study, grade level and age of participants, sample size, assignment of subjects to treatments, types of treatments, and covariates employed in the studies. The dependent variables included such things as test format (multiple choice, essay, outline, short answer), level of test questions (knowledge, comprehension, application), and time of testing (immediate or delayed).

Where sufficient data were reported the effect size was computed with one of the following formulas:

$$ES = \frac{\bar{X}_E - \bar{X}_C}{S_C}$$

Where ES = effect size

$\bar{X}_E$ = mean of the experimental group

$\bar{X}_C$ = mean of the control group

S_C = standard deviation of the control group

$$ES = t\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

Where ES = effect size

n_1 = number of subjects in the experimental group

n_2 = number of subjects in the control group

t = t statistic reported

Only 40 studies were found which met the outlined criteria and which included information that lends itself to meta-analysis. From these studies 472 effect sizes were computed. These effect sizes were blocked by categories to ascertain any trends among the various studies.

Results and Implications: Of the effect sizes computed, 36% were negative and 64% were positive. There appeared to be a trend among the studies with many of the more recent studies reporting negative results. Overall, the analysis of the research studies produces various results. First of all, when the overall average effect size is considered, the analysis indicates that students may be aided in their understanding

of science concepts from textual materials. The overall effect size for all the studies considered was 0.57. This indicates that the control group was less able to respond to the questions on criterion measure than were the various experimental groups. This is important since it includes the totality of the studies. Even though there was approximately one-third of the studies indicating negative results, it appears that aids for selecting information and for structuring internal connections are useful if we wish to consider overall achievement as our criterion variable. Secondly, the effect size varied depending upon the type of outcome measure. However, in all cases, whether the measure was a multiple choice test, an essay test, a true-false test, or another type of measure, the effect size was positive. Additionally, it did not matter whether the outcome measures were prompted or not prompted, whether they were incidental or target. This indicates that the experimental group did better than the control group regardless of the type of dependent measure. The results did not indicate an overall advantage for one specific type of dependent measure. That is, students benefited from the aids in the textual material regardless of the specific type of treatment. The results of blocking the studies on other variables are not as clear. Many of the differences in computed effect sizes were quite small. This indicates that the structure of the study may not have influenced the results. That is regardless of such things as the assignment of subjects to experimental or control groups, the sample size, and the age of the participants the learning outcomes from structuring textual materials as in most cases beneficial. Other analysis are presently being done to clarify these later findings.

Discussion: Learning from textual type materials and learning from laboratory type situations will always be two integral parts of science education. Today with the microcomputer being used to simulate many laboratory type activities, knowledge about learning from the textual type materials may possibly become more important. The present study indicates that most students can be expected to benefit from forms of textual structuring that aid them in selecting the important concepts and also that aid them in making internal connections within the presented materials. It is possible that computer presentation of textual materials will make this evern more feasable. However, there are many research questions yet to be studied when we consider learning science material from text. Will we be able to show that learning from textual materials on the microcomputer is similar to learning from textual materials in a book or paper format? Can we structure the materials in such a way that material is presented to students in a manner which facilitates their type of cognitive processing? It appears that this approach is better than trying to provide a common background for students on every science subject. Individual differences in students would generally indicate that this is an impossible task. This analysis of research studies related to learning of science content from written materials indicates that there are techniques which influence outcomes in a systematic and predictable manner. However, additional studies are necessary to continually update our knowledge in this area and to relate this knowledge to the new technological advances in the teaching of science.

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